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Exploring community risk perceptions of climate change - A case study of a flood-prone urban area of Taiwan

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ABSTRACT

The regional phenomenon of heavy rainfall under global climate change is extremely likely to induce flash floods in flood-prone urban areas and endanger the lives and safety of residents. Due to its low-lying land and the overdevelopment of urban areas, Hsinchuang District in New Taipei City, situated in the Taliaokeng River basin, is subject to routine flooding on some of its streets after heavy rainfall in a changing climate. Faced with the challenge, this study provides insights into risk perceptions of flood-prone communities that should be factored in risk communication to foster adaptive actions in responding to climate change. It is underscored that community perception of climate change is a factor in increasing local awareness of climate risk. The study used Driver-Pressure-State-Impact-Response (DPSIR) cause-effect model as the information flow framework to assess community vulnerability and risk perceptions throughout semi-structured interview process. The focus was put on how the community risk perceptions were shaped in the context of social amplification of risk in responding to climate change. This methodological approach underscores community risk perceptions are an inherent part of the decision-making process, and helps to enhance adaptive actions of flood-prone communities. The study also underlined the risk communication in groups and social networks that contribute to the integration of structural and non-structural measures to advance understanding of community risk perceptions of future climate.

1. Introduction

Extreme weather and climate events (climate extremes) offer significant signals about climate risks and resilience in responding to changes that are already unavoidable (Huber & Gulledge, 2011; IPCC, 2012a, 2012b). The change in the probability of occurrence of climate extremes indicates that it occurred rarely over protracted periods but may occur more frequently in the future. It concerns the interaction of climatic, environmental, and human factors that can lead to impacts and disasters. It is noted that increasing intensity of extreme rainfall under climate change is of significant societal concern, with rainfall-derived floods being one of the most costly and dangerous natural hazards worldwide (Hallegatte, Green, Nicholls, & Corfee-Morlot, 2013; Westra et al., 2014). The Intergovernmental Panel on Climate Change (IPCC) has stated that floods will occur more frequently in South Asia and Southeast Asia in the future (IPCC, 2007). Taiwan may be the place on Earth most vulnerable to natural hazards, with 73% of its land and population exposed to three or more hazards (Dilley, Chen, Deichmann, Lerner-Lam, & Arnold, 2005; Ferry, 2016).

The frequency of rainfall shows a decreasing trend for lighter rain and an increasing trend for heavier rain in Taiwan (Tu & Chou, 2013). In Taipei, for example, total rainfall increased but the number of rainfall days decreased in 2011, indicating an increase in rainfall intensity in this area (Lu, Cho, Li, Li, & Lin, 2012). Rainfall levels have shown a significant increase in the typhoon period but a declining trend in the non-typhoon period, indicating greater extremes between typhoon rainfall and non-typhoon rainfall. Typhoon rainfall has affected Taiwan's rainfall levels for nearly 10 years (Tu & Chou, 2013). For example, Typhoon Morakot in 2009 caused large-scale flooding and loss. As an example of a severe disaster caused by climate change, Typhoon Morakot led to nearly 700 dead and missing, showing the impact of extreme rainfall. Disasters resulting from extreme rainfall have had considerable impacts, such as high casualties and economic losses. The level and scale of flooding vary with the temporal and spatial distributions of rainfall (CEPD, 2012). Being prone to natural disasters and with social changes occurring in Taiwan, the disasters caused by climate change in the greater environment have had considerable impacts indeed.

From the 1970s to the end of 2010, the number of weather-related events occurring every 10 days in Taiwan also showed an obvious increasing trend. According to the natural disaster statistics of the National Fire Agency of Taiwan (NFA), there were 32 weather-related

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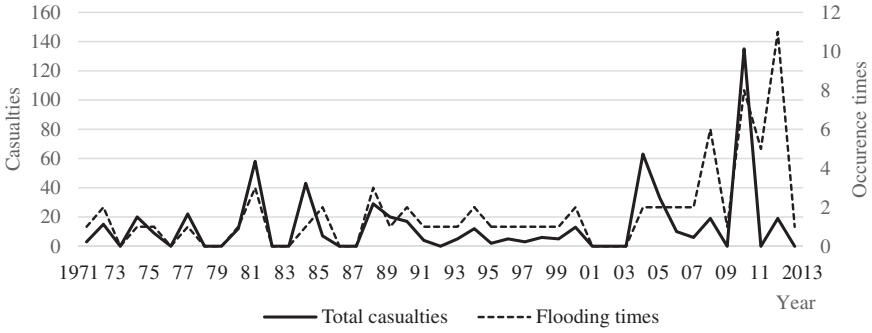

Fig. 1. Casualties and losses caused by floods in Taiwan on a bi-yearly basis (NFA, 2014).

disasters such as floods, wind disasters, heavy rain, and flash floods in the 1970s; but from 2001 to 2010, more than 79 such disasters occurred, resulting in as many as 1348 people dead and missing (Chen & Lin, 2011). Among these weather-related disasters, the number of floods in Taiwan rose the most obviously, with a year-by-year increasing trend being seen. Both casualties and losses caused by floods increased year by year (Fig. 1). In recent years, the severity of major floods and typhoons is attributed to the increasing occurrence of extreme rainfall. Fig. 1 shows that extreme climate conditions have a far-reaching impact on the environment, and will be even a great risk to human safety in the future (CEPD, 2012).

Overall, climate change leads to changes in global hydrological systems, resulting in changes in rainfall intensity and distribution. The consequent regional heavy rainfall results in river flow changes, which will probably exacerbate flooding in flood-prone urban areas. In the future, however, the intensity of extreme rainfall under climate change will exceed the capacity of the regional drainage system or the embankment protection standards, thereby increasing the risk of flooding. In particular, the current frequency of flooding in areas with high flooding potential may increase. Therefore, climate change adaptation measures must be carried out as early as possible to reduce community vulnerability, and flood management systems for flood-prone areas should be explored to support decision-making in the face of climate change (CEPD, 2012). In other words, in regarding the irreversible impacts of and uncertainties about climate change, people should be concerned with their own or group vulnerability covering both environmental degradation and human adaptability (adaptive capacity) (Biesbroek, Termeer, Klostermann, & Kabat, 2014; Eriksen, Nightingale, & Eakin, 2015; van Buuren, Keessen, van Leeuwen, Eshuis, & Ellen, 2015).

Faced with climate impacts, this study takes the flood-prone communities in Hsinchuang District, New Taipei City, situated in the Taliaokeng River basin, as an example for exploring community risk perceptions of climate change, which should be factored in risk communication (Ndamani & Watanabe, 2007). Risk perception is defined in this study as people's knowledge performance through information flow in the context of social amplification of risk (Kasperson et al., 1988; Mase, Cho, & Prokopy, 2015), which helps to foster adaptive actions in responding to the cause and consequences of climate change. The focus was put on how the community risk perceptions were shaped on both environmental degradation and resident adaptability. This methodological approach underscores community risk perceptions are an inherent part of the decision-making process (Klein & Cerully, 2007; Williams & Noyes, 2007), and helps to enhance adaptive actions of flood-prone communities as they manage floods as a group, and can serve as a reference for the development of climate resilient communities.

In order to understand and simplify the complex climate-community interactions, the Driver-Force-Pressure-State-Impact-Response (DPSIR) cause-effect model was used as the information flow framework to explore the community vulnerability and risk perceptions of climate change in the context of social amplification of risk and throughout the semi-structured interview process. It is noted that climate change impacts are closely related to each individual and their risk perceptions are the major cause of unequal adaptive actions. It is also noted that knowledge gap leads to vulnerability and maladaptation and indicates the importance of including human adaptability in responding to climate change (Giddens, 2009; Granberg & Glover, 2014; IPCC, 2014; Lahsen, 2010; Newsham & Thomas, 2011).

2. Methods

2.1. Study site

The study site is flood-prone communities in the lower reaches of the Taliaokeng River in New Taipei City. Due to the low-lying land and change in land use of the urban areas, runoffs have increased and some areas have experienced routine flooding after rainfall, threatening local residents' safety. In 2012, Typhoon Sura struck the city with heavy rain. Due to the high water level of the Dahan River, the water control gate of the Taliaokeng River was closed, and the floodwater could not be immediately drained by the pumping station alone. As a result, rainwater in urban areas could not be discharged to the Taliaokeng River, leading to ponding water in low-lying sections of the Qionglin Road near the water control gate. In view of the flood issue in these areas, the government invested in the construction of the Zhonggang Main Drainage scheme and promoted the Taliaokeng drainage system improvement project in order to resolve a local flooding issue that had existed for years. Therefore, the government built the No. 2 pumping station for the Taliaokeng River, a major flood control project in the Regulation Project of Flood-prone Areas.

The pumping station equipment quickly drains internal waters when typhoon floods occur and is usually set near the water control gate. When the river water level rises to a level at which the internal water cannot be discharged, the pump in the pumping station needs to be used to pump the water to the main river beyond the dyke to protect the living environment from flooding, thereby preventing casualties and losses to residents (NTCG, 2016). As part of this project, it is planned to build five pumping units in total and increase the number of drainage gates from four to six. In this case, water will be rapidly discharged into the river, reducing the flooding risk in Hsinchuang District.

Using Hsinchuang's flooding potential map (precipitation: 600 mm) (NCDR, 2017), we first conducted preliminary interviews with the residents in the flood-prone area of the Taliaokeng River basin. It was found that the heavily flooded areas were mainly distributed in the lower reaches of the Taliaokeng River. The upstream flood-prone area has not been flooded since a renovation project was completed 10 years ago. Therefore, the scope of the study site was narrowed from seventeen communities located around the river basin, which had been delineated according to the flooding potential map of Hsinchuang, down to seven communities of C1, C2, C3, C4, C5, C6, C7 (that is, Haishan, Fengtai, Qionglin, Quanan, Fengnian, Wenheng, and Guotai) located in the flood-prone sections in Hsinchuang District for in-depth interviews (Fig. 2).

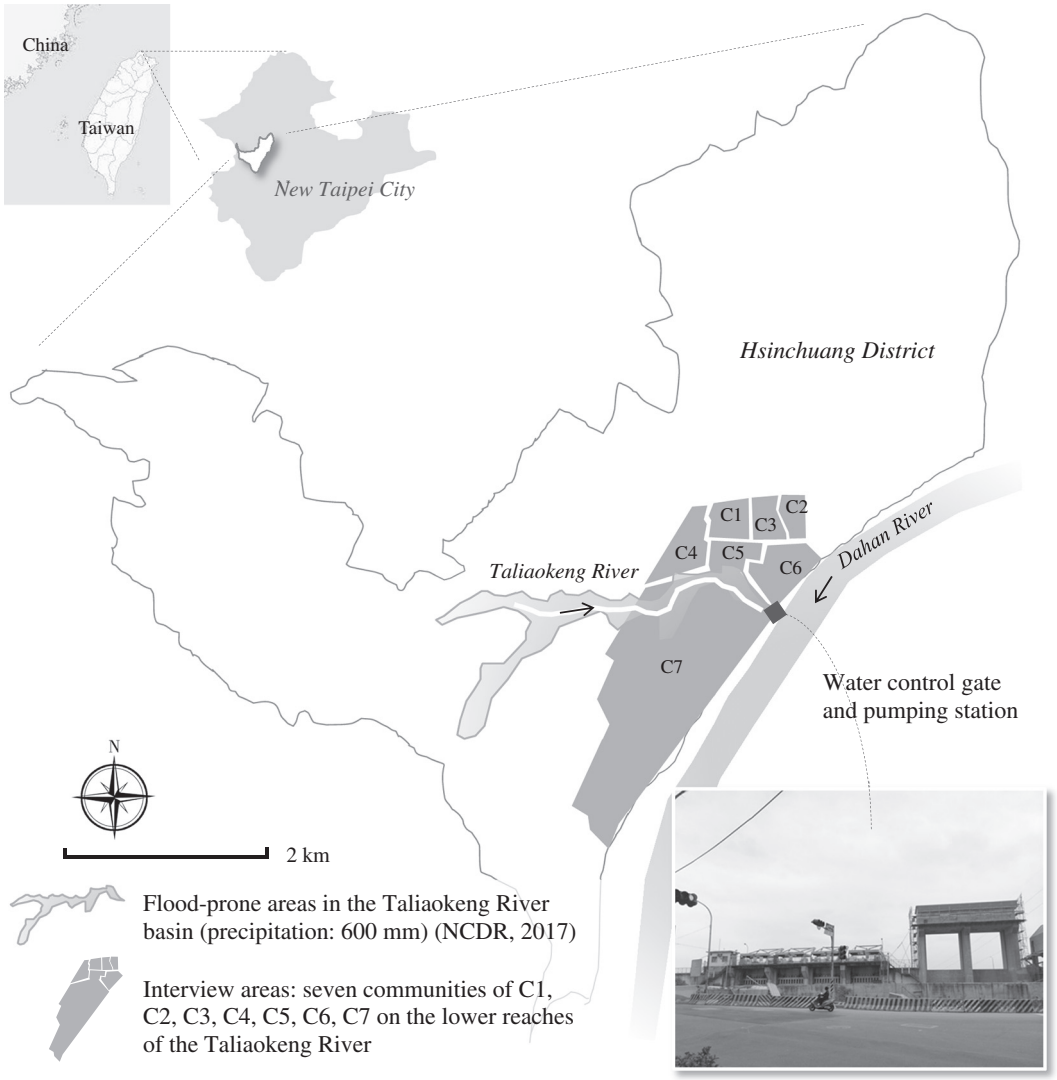

Fig. 2. Study site that covers flood-prone areas and interview areas.

2.2. DPSIR information flow framework

Anthropogenic climate change results from humans entering an environment whereby cause-effect nature of a system means that there is potential for the social amplification of risk (Hagen, 2015; Kasperson et al., 1988), which modifies perceptions of risk in terms of risk communication (APA, 2009) and thus the information flow. As such, the DPSIR information flow was used to understand and simplify the complex climate-community interactions in the context of social amplification of risk and as a starting point for semi-structured interviews. The DPSIR framework has been commonly applied in academic research to describe the causal relationship between natural environment and human activities (EEA, 2007). In addition, in order to understand and simplify the complexity of a system, the DPSIR approach has long been a valuable problem-structuring framework used to assess the causes, consequences and responses to change in a holistic way (Elliott et al., 2017; Ojeda-Martínez et al., 2009).

In other words, the DPSIR framework helps in the exploration of anthropogenic climate change and highlights community vulnerability under different impacts, and reflects varying responses. In addition, recognizing the complex climate-community dynamics, the DPSIR framework provides the researchers an opportunity to sample the interviewees to explore their risk perceptions and experience shaped over time (Chiang, Tsai, Chang, Chen, & Huang, 2014). The model helps encourage and support political decision-making by identifying clear steps in the causal chain that can be broken by policy action. More crucial is that the model presents a systems analysis view that may elicit a societal response that directly feeds back to the drivers, the pressures, the state, or impacts through adaptive actions (EEA, 2007). In the study, the DPSIR model is described as follows (Fig. 3):

- Driver (D): climate change is occurring and could affect our society.
- Pressure (P): extreme rainfall is a likely effect of climate change and can be seen as environmental pressure.
- State (S): flooding in communities caused by extreme rainfall is challenging local environment and resident conditions.
- Impact (I): community risk resulting from flooding exerts impacts on local environmental degradation and resident adaptability, changing people's risk perceptions.
- Response (R): active actions need to be taken in responding to Driver, Pressure, State, and Impact.

2.3. Vulnerability and risk perception

Regarding the impacts of and uncertainties about climate change in the future, vulnerability has become the focus of numerous studies (Adger et al., 2009; Berkes & Jolly, 2002; Chiang et al., 2014; Chiang & Huang, 2016; Cutter, 2003; Feldman & Ingram, 2009; Moser & Ekstrom,

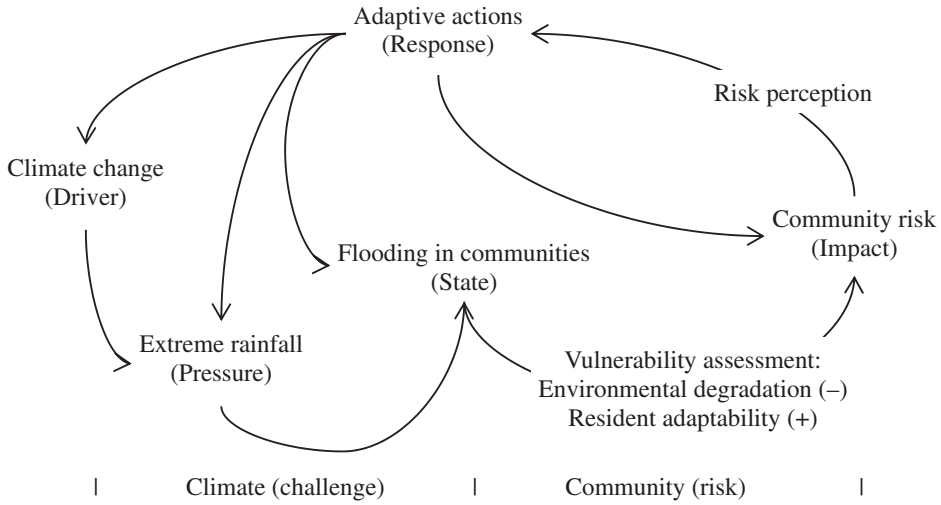

Fig. 3. Driver-Pressure-State-Impact-Response (DPSIR) cause-effect model (EEA, 2007) was used as the information flow framework to explore the community risk perceptions of climate change in the context of social amplification of risk that addresses complex climate-community interactions.

2010; Rannow, Loibl, Greiving, Gruehn, & Meyer, 2010; SEI, 2016), and is often associated with the environmental and individual status changes that people are aware of, thereby affecting people's perceptions of risks and even the adaptive actions to be taken. The Intergovernmental Panel on Climate Change indicated that in climate change, vulnerability is the degree to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). Adaptive capacity (adaptability) influences risk perceptions, and perceived risk determines the residents' responses (Söberg, 2000; Vandeventer, 2012). Adger, Nick, Bentham, Agnew, and Eriksen (2004) have also stated that vulnerability is broadly defined as the possible damage that a specific system suffers from when exposed to pressures, which helps in examining its adaptability; therefore, adaptability can be interpreted as the behaviours of a system to modify or change its traits so that it can correct and respond to the existing or unexpected pressure.

In this study, vulnerability assessment primarily involves community's environmental degradation and resident adaptability (Adger et al., 2009; Cutter, 2003; Füssel & Klein, 2006; Romieu, Welle, Schneiderbauer, Pelling, & Vinchon, 2010; Rounsevell, Dawson, & Harrison, 2010; Vogel, Moser, Kasperson, & Dabelko, 2007), which determine community risk perceptions and subsequently their adaptive actions in responding to climate change (Fig. 3). In addition, this study explored the causes and consequences of community vulnerability using the DPSIR framework in the context of the social amplification of risk. Taking communities in the lower reaches of the Taliaokeng River in Hsinchuang District as an example, we examined how much local residents understood the environmental conditions and their own situations in case of flooding and their risk perceptions of environmental impacts. It is noted that climate extremes occurring under global climate change have led to regional impacts, reflecting regional vulnerability and creating local climate risks. Risk perceptions should be factored in risk communication to foster adaptive actions under climate change. Based on the perspectives mentioned above, we propose a community vulnerability and risk perception assessment approach as follows (Table 1):

- Community vulnerability: the vulnerability involves two perspectives, namely the environmental degradation referred to damage level (negative value) and the resident adaptability referred to tolerance level (positive value), which can be represented as environmental degradation (−) and resident adaptability (+). It is of concern that every person has the basic capability to be adaptable - without this we would not be able to function in the world (Prince, 2012).
- Categorical values: to understand the different residents' risk perceptions of change, three categories representing low, medium, and high with values from 1 to 3, respectively, were used to evaluate both environmental degradation (damage level) and resident adaptability (tolerance level) on river flood risk (Chiang et al., 2014; Chiang & Huang, 2016). The categorical values in three degrees underline the aforementioned social amplification of risk framework that complicates how people perceive, evaluate, and act on climate change risks, and addresses integrated knowledge performance. This study used categorical values in three degrees to represent Low (Adger et al., 2004), Medium (Adger et al., 2009) and High (Amundrud & Aven, 2015), and provide a common index that represents the risk perception. Five perception states are defined: Discouraged (− 2), Worried (− 1), No feeling (+ 0), Acceptable (+ 1), and Resistant (+ 2).
- Environmental degradation: the indicators comprise buildings, environment, and infrastructure, which can be represented as Building (− 1), Environment (− 1), and Infrastructure (− 1), respectively. Three levels are defined: Low (− 1), Medium (− 2), and High (− 3).
- Resident adaptability: the indicators comprise resident skill, knowledge, and support, which can be represented as Skill (+ 1), Knowledge (+ 1), and Support (+ 1), respectively. Three levels are defined: Low (+ 1), Medium (+ 2), and High (+ 3).
- Risk perception: as aforementioned, risk perception is defined in this study as people's knowledge performance through information flow in the context of social amplification of risk. That is, risk perceptions are communicated through different signals that can amplify or attenuate the perception of risks and their manageability (Hagen, 2013), and humans have the ability to perceive the risk throughout interpretation of sensory information to represent and understand the environment. As such, based on the aforementioned environmental degradation and resident adaptability interviewees' risk perceptions in the study were calculated and compared as follows (Chiang & Chang, 2017; Chiang & Ling, 2017):

$$f(x, y) = x + y \quad (1)$$

where.x refers to environmental degradation (value) focused on building, environment, infrastructure (indicator) and is rated from − 1 to − 3;y refers to adaptive capacity (value) focused on skill, knowledge, and support (indicator) and is rated from + 1 to + 3;$f(x, y)$ refers to the common index that represents risk perception.

The community vulnerability and risk perception assessment framework and method mentioned above help in the analysis of interview information obtained through interviews and in understanding residents' awareness of floods in communities. Then, residents' perceptions of environmental impacts were explored (with quantified scores) to serve as the references for examining their responses. The measurement indicators, comprising community environmental

Table 1
Community vulnerability and risk perception assessment approach.

Community vulnerability	Environmental degradation (damage level)	+ Resident adaptability (tolerance level)	= Risk perception (awareness state)
Indicator (value)	Building (−1) Environment (−1) Infrastructure (−1)	Skill (+1) Knowledge (+1) Support (+1)	
Level/state (value)	Low (−1 = −1) Medium (−1–1 = −2) High (−1–1–1 = −3)	Low (+1 = +1) Medium (+1 + 1 = +2) High (+1 + 1 + 1 = +3)	Discouraged (−3 + 1 = −2) Worried (−2 + 1 = −1) Worried (−3 + 2 = −1) No feeling (−1 + 1 = 0) No feeling (−2 + 2 = 0) No feeling (−3 + 3 = 0) Acceptable (−1 + 2 = +1) Acceptable (−2 + 3 = +1) Resistant (−1 + 3 = +2)

degradation and resident adaptability, were generated based on a literature review and the preliminary interviews (Chiang et al., 2014; Chiang & Chang, 2017; Chiang & Huang, 2016; Chiang & Ling, 2017).

2.4. Semi-structured interviews

The semi-structured interview process was conducted using a focus group that had experienced more than one flooding in the past 10 years (2003–2013; Fig. 1) to gain a deep understanding of the information provided by the interviewees, that is, people's knowledge performance through information flow in the context of social amplification of risk. As such, the DPSIR cause-effect framework was used to explore interviewees' environmental degradation (damage level) and resident adaptability (tolerance level) in terms of vulnerability through the guidance of simple and clear assessments done by researchers to determine the risk perceptions of interviewees. The interview process emphasizes that interviewees can express their opinions as they like as long as the whole guidance is followed. Therefore, the reliability of interview materials is irrelevant to the number of samples (Carmin, 2009; Eliasson, 2000; Jamshed, 2014; Laforest, 2009; Newton, 2010; Stott, 2014). Once the interviewees' opinions began to repeat, the interviews could be ended. We underlined that studies that use more than one method require fewer participants, as do studies that use multiple (very in-depth) interviews with the same participant (Lee, Woo, & Mackenzie, 2002; Mason, 2010). For this reason, only 16 respondents (A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P) were included in the study, distributed across the seven flood-prone communities (C1–C7) (Fig. 4).

The semi-structured interview process continued until the respondent either repeated the same answers or was not able or willing to answer (Tools4dev, 2015a), each lasting between 20 and 45 min (Chiang & Chang, 2017).

The semi-structured interview underscores that the interview results vary with the interviewer's life experiences and stand in the face of questions, and sometimes surprising results may be obtained. The interview content qualifies for analysis which will help deeply understand the interviewee's personal background and life experience (Jamshed, 2014; Newton, 2010). That is, this study underscored that the risk events occur in a societal context and that the residents who provide a vital workforce would acquire an understanding of flood risks and have adopted acceptable levels of these risks. It was also argued that the interviewees are able to tell a “story” about the environmental impacts and their response (Kok, Gramberger, Simon, Jäger, & Omann, 2011). The interview process underlines the concept of social amplification of risk framework that modifies perceptions of risk in terms of risk communication (APA, 2009; Hagen, 2015; Kasperson et al., 1988). It was noted that risks are communicated through different signals such as images, and these signals can amplify or attenuate the perception of risks and their manageability (Hagen, 2013).

3. Results and discussion

3.1. Interview information

Regarding the interview design, we first established the keywords

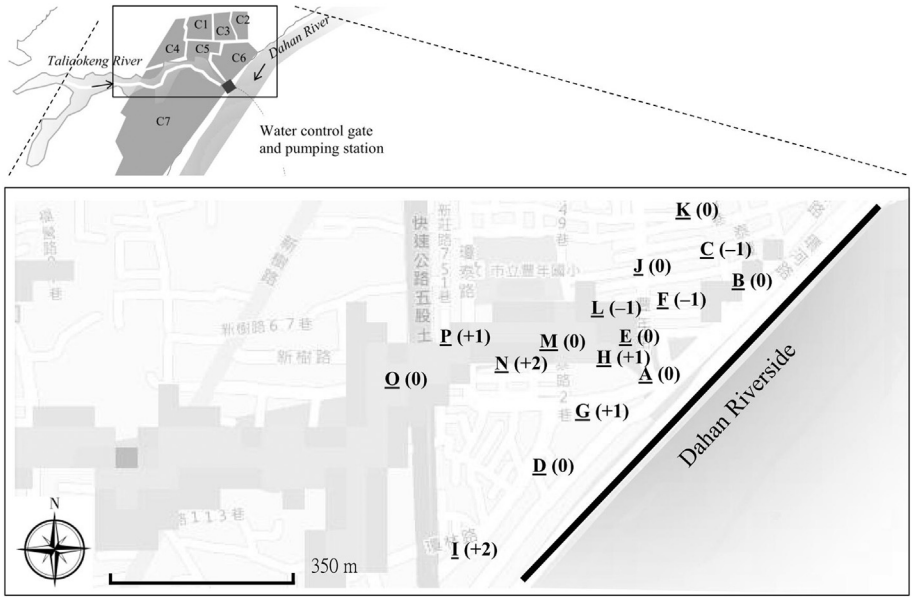

Fig. 4. Interviewees' (A–P) geographical location in relation to the riverside (in the brackets are perception values).

Table 2
Interview information and analysis results.

Interviewee code (age, gender, occupation)	Environment degradation (−) (building, environment, infrastructure)	+ Resident adaptability (+) (skill, knowledge, support)	= Risk perception (−, 0, +) (discouraged, worried, no feeling, acceptable, resistant)
A (52, female, housewife)	Damage level: − 3 The house will be devalued (Building–1), it is the government's business if the state of bridges and roads gets out of control (Infrastructure–1), and there will be a lot of sludge and garbage, which are difficult to clean up (Environment–1).	Tolerance level: + 3 It is better to dig another water channel (Support + 1). It is said that sandbags can be stacked in the drains (Support + 1). Important stuff is moved to the first floor (Skill + 1).	Perception state: + 0 In the face of the current situation: No feeling
B (38, male, retailer)	Damage level: − 1 Flooding reached about 30 to 40 cm in buildings (Building–1).	Tolerance level: + 1 During Typhoon Nari, the pumping station did not operate, so flooding resulted (Support + 1).	Perception of flooding: + 0 In the face of the current situation: No feeling
C (42, male, salesman)	Damage level: − 2 Flooding was due to the dyke being built (Infrastructure–1). The flooding reached almost to my ankles (Building–1).	Tolerance level: + 1 Flooding was due to untimely flood discharge (Knowledge + 1).	Perception of flooding: − 1 In the face of the current situation: Worried
D (62, male, manager)	Damage level: − 2 The expenditure on building dykes and pumping stations is large (Infrastructure–1), and much sludge is formed during flooding (Environment–1).	Tolerance level: + 2 Now the community is still faced with flooding if there is heavy rain (Knowledge + 1). The river rose too fast, especially during typhoons on the first and fifteenth days of a particular month (Knowledge + 1).	Perception of flooding: + 0 In the face of the current situation: No feeling
E (46, female, retailer)	Damage level: − 1 Flooding would have been avoided if pumping stations were properly established (Infrastructure–1).	Tolerance level: + 1 Flooding does not occur anymore. In the past, flooding occurred about three times a year, with a height of 50 cm (Knowledge + 1).	Perception of flooding: + 0 In the face of the current situation: No feeling
F (55, male, technician)	Damage level: − 2 After the dyke was built (Infrastructure–1), flooding occurred less frequently, but some people moved away due to flooding (Building–1).	Tolerance level: + 1 The water barrier in front of my door does not work well (Support + 1).	Perception of flooding: − 1 In the face of the current situation: Worried
G (56, male, teacher)	Damage level: − 2 The ceramic tiles on buildings will come away (Building–1), and there will be many cockroaches in the sludge (Environment–1).	Tolerance level: + 2 Flooding occurred during typhoons and heavy rain (Knowledge + 1). Sand bags were stacked and things were moved to the first floor (Support + 1). A water barrier gate was set up in front of the door (Support + 1).	Perception of flooding: + 1 In the face of the current situation: Acceptable
H (46, male, engineer)	Damage level: − 2 The environment is dirty (Environment–1). Regarding the ongoing No. 2 pumping station project for the Taliaokeng River, I think it is okay as long as it is useful (Infrastructure–1).	Tolerance level: + 3 Flooding always occurs in May and June of each year (Knolwedge + 1). The flooding height is about 50 cm and the ground floor flood level was higher (Knowledge + 1). Flooding has not occurred since the pumping station was built (Support + 1).	Perception of flooding: + 1 In the face of the current situation: Acceptable
I (51, male, craftsman)	Damage level: − 1 The electricity has been cut off and there is a lot of sludge (Environment–1).	Tolerance level: + 3 In the Typhoon Toraji period, the flooded water reached up to people's knees (Knowledge + 1). Sandbags can be used to block the water (Support + 1). Stuff is moved to the first floor (Skill + 1).	Perception of flooding: + 2 In the face of the current situation: Resistant
J (45, female, babysitter)	Damage level: − 2 The government gives too few subsidies for flooding relief (Infrastructure–1). The flooded water was dirty and smelly every time (Environment–1).	Tolerance level: + 2 There was no flooding in the past, but since the water barrier was built, flooding began (Support + 1). Flooding occurred less frequently over the past several years because the rainfall has not been high enough. If flooding does not occur when rainfall reaches 50 mm per hour, then the construction works really function (Knowledge + 1).	Perception of flooding: + 0 In the face of the current situation: No feeling
K (46, female, housewife)	Damage level: − 2 Buildings are flooded (Building–1). Damage was caused because the drainage system built by the government is bad. I believe as long as the pump is well maintained, flooding will be avoided (Infrastructure–1).	Tolerance level: + 2 The ground floor was raised (Knowledge + 1). Now a flood warning will be broadcast to make residents aware (Support + 1).	Perception of flooding: + 0 In the face of the current situation: No feeling
L (66, male, retiree)	Damage level: − 2 The house is flooded (Building–1). There is a lot of sludge and dirty water (Environment–1).	Tolerance level: + 1 Just let it flood (Knowledge + 1).	Perception of flooding: − 1 In the face of the current situation: Worried
M (38, male, retailer)	Damage level: − 2 Flooding does not occur here due to the high terrain. There was once a flooding event during Typhoon Nari (Environment–1) because the pumping station here was still under construction at that time. Flooding was caused due to a gap in the planning of the project (Infrastructure–1).	Tolerance level: + 2 Taifeng and Fengnian streets are most prone to flooding, with the flooded water rising to about 100 cm each year (Knolwedge + 1), so a water barrier gate was set up in front of each door (Skill + 1).	Perception of flooding: + 0 In the face of the current situation: No feeling
N (58, male, retailer)	Damage level: − 1 There is a lot of sludge (Environment–1).	Tolerance level: + 3 The terrain here is low, so flooding often occurred in the past (Knowledge + 1). During flooding, I had to sweep the water and move stuff (Skill + 1). The cleaning team came to help (Support + 1).	Perception of flooding: + 2 In the face of the current situation: Resistant

(*continued on next page*)

Table 2 (*continued*)

Interviewee code (age, gender, occupation)	Environment degradation (−) (building, environment, infrastructure)	+ Resident adaptability (+) (skill, knowledge, support)	= Risk perception (−, 0, +) (discouraged, worried, no feeling, acceptable, resistant)
O (62, female, housewife)	Damage level: − 2 The mud is not a problem for my house (Environment–1). The government will construct a lot of roads (Infrastructure–1).	Tolerance level: + 2 Flooding has not occurred often in the past several years. It is mostly pools of water, rising to about 100 cm (Knowledge + 1). The stuff was moved to the first floor (Skill + 1).	Perception of flooding: + 0 In the face of the current situation: No feeling
P (38, female, babysitter)	Damage level: − 1 The living environment is OK (Environment–1).	Tolerance level: + 2 I noticed the flooding situation (Knowledge + 1), and I dealt with it based on experience (Skill + 1).	Perception of flooding: + 1 In the face of the current situation: Acceptable

for the aforementioned vulnerability indicators and then designed the semi-structured interview and analysis process before interviewing the local residents in the flood-prone communities in the lower reaches of the Taliaokeng River in Hsinchuang District. The interview content includes not only the interviewees' opinions on the community environmental degradation and resident adaptability, but also their background information, including gender, age, and occupation. We marked the locations (workplace or home) where interviewees were interviewed on the map during the interviews, with the purpose of understanding the relationship between these locations and the flooded area. In addition, during the interview process, interview information (key messages) from all 16 interviewees focused on environmental degradation (building, environment, and infrastructure) and resident adaptability (skill, knowledge and support) for assessing community vulnerability and risk perceptions were scored, calculated, and sorted in Table 2.

That is, this study points out that the accumulation of different types of information helps knowledge formation, and the understanding of such knowledge helps to form perceptions of risks and starts the adaptive actions (Amundrud & Aven, 2015; Aven, 2013; Duffield & Whitty, 2015; Pahl-Wostl et al., 2013; Spiekermann, Kienberger, Norton, Briones, & Weichselgartner, 2015). Therefore, this study assumed the key message of each interviewee to be a social impact during the vulnerability assessment. Based on the scores of two types of indicators, this study first assumed that each impact had the same weight (weight not counted) and counted the score by addition (Colburn et al., 2016; Dumenu & Obeng, 2016; McCalman et al., 2016; Nguyen, Bonetti, Rogers, & Woodroffe, 2016).

3.2. Interpretation of analysis results

Based on the interview information analysis results that address the risk perception as aforementioned people's knowledge performance through information flow in the context of social amplification of risk, we interpreted environmental degradation, resident adaptability, and risk perceptions of communities as follows:

Environmental degradation (Fig. 5)

- Nearest to the riverside: interviewee A was nearest to the riverside and the Taliaokeng basin, and therefore suffered from more floods and people had the strongest perception of the environmental impacts in the community.
- Far from the riverside: interviewees B, C, D, E, F, I, and J were interviewed at a similar distance from the riverside. It can be seen that their perceptions of environmental impacts were weaker than Interviewee A. Interviewee K was dissatisfied with the community environment and government actions. For example, K said: 'I think the drainage system built by the government is very bad; the pumping motor always powers off and cannot pump water, so I have strong feelings about the impacts.' The place where Interviewee M was interviewed was near to the place where Interviewee N was interviewed. Interviewee N was nearer to the Taliaokeng River basin, and, therefore, suffered from more floods and had a stronger perception of the environmental impacts than Interviewee P.
- Farthest from the riverside: interviewee O was the farthest from the riverside. Since the location was not often flooded, Interviewee O had a relatively weak perception of flooding impacts. Interviewee P had suffered from floods in the past but had no feeling about the environmental impacts of floods.
- Interviewees H, G, M, N, and O around the Taliaokeng River had almost the same perceptions of environmental impacts. This indicates that the flood-prone areas are affected not by the whole drainage basin of a river but the estuarine regions in the lower reaches of the river. Therefore, the areas at the estuary are the main flooding-prone areas. The farther residents are from the lower reaches, the less impact is caused by flooding. This is because residents mostly feel the environmental impacts caused by flooding. However, the perception degree depends on how far the residents lived from the estuary and their awareness of the situation. Therefore, perceptions vary with individuals.

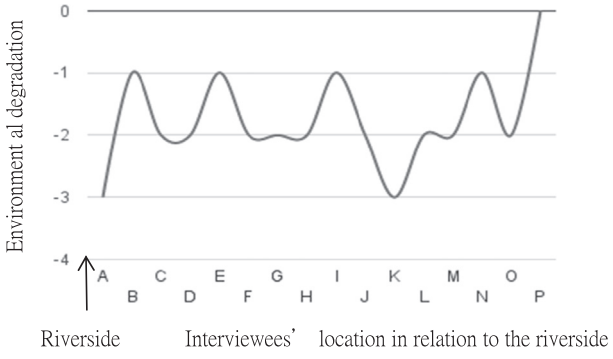

Fig. 5. The correlation between environmental degradation and interviewees' location to the riverside.

Resident adaptability (Fig. 6)

- Nearest to the riverside: interviewee A had the strongest perception of community risks and the strongest adaptability.
- Far from the riverside: interviewees nearer to the Taliaokeng River and riverside had higher adaptability. Interviewees C, D, E, and F are almost equally distant from the riverside. Interviewee D, who was nearer to the Taliaokeng River, brought up specific issues. For example, 'Now the Taifeng Street will still be flooded as long as there is heavy rain'. The reason for flooding was that the river water rose too fast. In particular, on the first and fifteenth day in a particular month, the river water rose very fast, so the score was high. The score depends on whether an interviewee proposes specific flood impacts and has the capability to adapt to floods. For example, interviewee K participated in the community assembly to discuss flood issues and raised the floor of their first-floor store, and therefore got a higher score. Interviewee L took a negative attitude

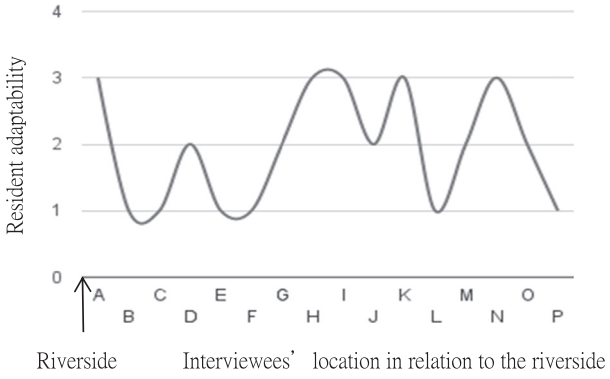

Fig. 6. The correlation between resident adaptability and interviewees' location to the riverside.

and just let the house flood, and therefore got a lower score.

- Farthest from the riverside: interviewee P did not mention the actions taken in case of flooding, and therefore got a lower score.
- It can be seen from Fig. 6 that resident adaptability depends on residents, own capabilities and does not relate to how far they live from the Taliaokeng riverside.

Risk perception (Fig. 7)

- Nearest to the riverside: interviewees A, B, C, D, E, and F were nearer to the riverside. Their locations were heavily flooded areas. The score −1 or 0 indicates that although the community environment (−) was affected due to floods, residents (+) developed their own adaptation methods. However, negative values in the curve also indicate that it is insufficient to solely depend on residents to resolve flood issues. The scores of interviewees A, B, C, D, E, and F show how community residents cope with floods. Although they were accustomed to floods, they still felt disgust about flood impacts.
- Far from the riverside: the scores of interviewees G, H, I, J, and K showed positive growth. Interviewee I's response was mostly restricted to his own home environment. He was less affected or not affected by the impacts on the community environment. In other words, he did not care about the community environment. However, he also provided a specific adaptation plan due to the impacts of floods on his country, so his score was positive and high.
- Farthest from the riverside: interviewees O and P were the farthest from the riverside. Their locations were flood-free areas. The impacts of floods on the environment were not an urgent issue for them anymore. It can be seen that the score of the community environmental degradation was high.

Following the comparative analysis of interviewees' locations, it can be seen from the figure that whether residents experience floods depends on how far they live from the riverside and the Taliaokeng River. According to the interviews, residents themselves observed the water levels of the river but not the switching status of the pumping station or the water control gate. According to the interviews, residents living both near the pumping station and the riverside still experienced flooding. It can be seen that distance from the river is an important factor in determining whether this region experiences floods. However, the ability to adapt to floods depends on residents' knowledge and ability. Floods have been dealt with for many years, but with no effective actions being taken. We believe that extreme climate issues will become more serious under climate change in the future. To address this problem, the government should, in cooperation with residents, integrate their respective knowledge and skills via an adaptation and management system to adapt to the impacts and uncertainties arising from climate change.

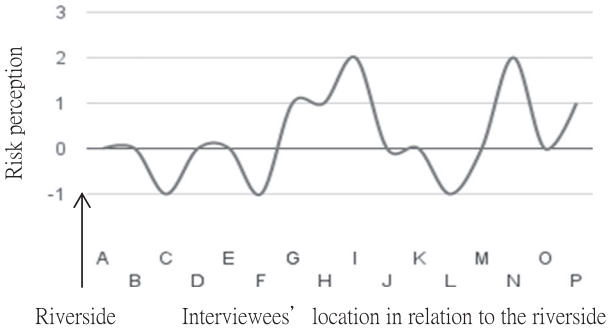

Fig. 7. The correlation between risk perception and interviewees' location to the riverside.

4. Conclusions

Regional heavy rainfall under global climate change may probably exacerbate flooding in flood-prone areas and, hence, endanger residents' safety. In the face of this severe challenge, this study takes the flood-prone communities as an example for exploring community risk perceptions of climate change, and define risk perception as people's knowledge performance through information flow in the context of social amplification of risk, which helps to foster adaptive actions in responding to climate change. The focus was put on how the community risk perceptions were shaped on both environmental degradation and resident adaptability. In addition, the DPSIR information flow framework was applied to understand and simplify the complex climate-community interactions throughout the semi-structured interview process.

Exploring community risk perceptions of climate change through interview information analysis and interpretation helps to decrease community environmental degradation and resident adaptability in responding to floods under climate change, and provide a reference for the development of resilient communities. As residents live in a common community environment and cultural background, they can organize community resident groups, combine the common experience of the community, and integrate their respective strategies and adaptability in the face of common climate impacts to improve the communities' abilities to respond and cultivate climate resilience. Moreover, community should formulate effective adaptive actions, for example, early warning systems and related risk assessments, and develop various adaptation strategies, which would enhance community adaptability and mitigate the impacts of climate change. In general, climate change will result in individuals or groups having a certain degree of vulnerability. The impact level depends on the location of the particular region, the time, and the adaptability of the group. Exploring community risk perceptions helps to develop an understanding of how prepared a community is for dealing with a changing climate.

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